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# **CORN NITROGEN RATE RESPONSE AND CROP YIELD IN A RYE COVER CROP SYSTEM**

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## **Introduction**

Water quality impairment related to N loss from crop production fields continues to be a concern in Iowa, including meeting the USEPA nitrate-N drinking water standard and reducing N export to the Gulf of Mexico. Therefore, in-field production practices would be helpful to aid in reduction of nitrate leaching and movement to water systems. One practice identified in the science assessment for the Iowa Nutrient Reduction Strategy is use of a winter cereal rye (*Secale cereal* L.) cover crop, where a mean 31% (29% standard deviation) nitrate-N reduction would be expected, but with a 6% (22% standard deviation) corn yield decrease (SP 435). Due to cost, planting flexibility, success in establishment, and winter hardiness, winter rye has been a common cover crop choice. However, the impacts of winter rye on crop productivity differ among geographic areas and production systems, including the influence on N recycling and corn N fertilization requirement. With N returned to the soil as cover crop biomass degrades, is it immobilized by microbial processing of the cover crop biomass, or is it added to plant-available N during annual crop N uptake? The objectives of the research were to determine the impact of a winter cereal rye cover crop on corn N fertilization requirement and corn and soybean crop productivity.

## **Materials and Methods**

Study sites were initiated at four Iowa State University Research and Demonstration Farms fall 2008, with an additional site in northwest Iowa added fall 2010. The sites represent major crop production regions, soils, and climatic conditions in Iowa: Ames – central (Webster scl), Lewis – southwest (Marshall scl), Crawfordsville – southeast (Mahaska scl), Nashua – northeast (Floyd l), Sutherland – northwest (Primghar scl). All sites were in a no-tillage corn-soybean rotation, with both crops present each year. Treatments were arranged in a split-plot design with four replications. The main plot was winter cereal rye and no rye cover crop, and the split plot N rate applied to corn (0 to 200 lb N/acre in 40 lb increments) as side-dress coulter-injected urea-ammonium nitrate (UAN) fertilizer applied two to three weeks after planting. The rye variety was Wheeler, drilled after corn and soybean harvest at 1.0 bu/acre.

The aboveground rye biomass was sampled in the spring before control with herbicide at five to ten random 1-ft<sup>2</sup> areas (number depending on rye growth), with calculated dry matter (DM) adjusted for rye row spacing. Soybean and corn were planted in 30-inch rows, with the planters equipped with residue cleaner attachments. The intended planting of soybean was any time after rye control (glyphosate), and the corn planting waiting at least 7 days after rye control in an attempt to reduce allelopathic or other effects of the cereal rye on corn establishment and growth. The intent was to not overly delay corn and soybean planting. If conditions allowed, the attempt

was to control rye in mid- to late- April, but sometimes that was delayed until May due to wet soils.

A Crop Circle ACS-210 active canopy sensor (Holland Scientific, Lincoln, NE) was used to estimate corn canopy development (response to N rate and rye cover crop) at the mid-vegetative (V10) growth stage. The sensor was positioned mid-row and carried by hand through the middle of each plot (2-3 ft above the canopy) at a constant speed (5 ft/s). The reflectance measurements were captured on-the-go with a handheld computer and averaged across each plot. Reflected light values were used to calculate the normalized difference vegetative index (NDVI). Corn and soybean grain yields were determined by harvest with a plot combine and reported at 15.5% moisture for corn and 13% for soybean. Corn economic optimum N rate (EONR) and yield at the EONR (YEONR) were determined from regression models fit to the N rate response and using a 0.10 \$/lb N:\$/bu price ratio.

### Rye Cover Crop Production

Each year the rye was successfully established, but fall growth was low and variable due to seeding date and fall weather conditions. The majority of rye growth occurred in the springtime and varied among sites and years depending on spring temperatures, soil moisture, previous N rate, and timing of rye control before the next crop planting (Table 1). The northern sites often had lower rye biomass (DM) production, but dry conditions or early control had an impact also (for example the Lewis site). With the intent to not overly delay corn and soybean planting, the rye growth was often limited due to timeliness for control.

Table 1. Rye cover crop biomass dry matter before controlling growth with herbicide, 2009-2013.

Cover Crop	lb N/acre <sup>†</sup>	Ames	Crawfordsville	Lewis	Nashua	Sutherland
		----- lb/acre -----				
Before corn		726	840	585	384	214
Before soybean	0	1056c <sup>‡</sup>	1249c	766a	519b	635a
	120	1291b	1462b	880a	551ab	742a
	200	1750a	1989a	869a	724a	768a

<sup>†</sup> Nitrogen rate applied to the prior year corn.

<sup>‡</sup> Rye biomass amounts at a site followed by the same letter are not different,  $p \leq 0.10$ .

The higher previous-year N rate applied to corn tended to result in greater rye biomass, but that was not consistent among sites. The rye N uptake followed the amount of rye biomass produced. However, since the rye DM was low, the rye total N uptake was also low (Table 2). Across sites, the mean N uptake was 20 lb N/acre, and within specific treatments and sites the lowest was 2 lb N/acre and the highest 63 lb N/acre. These uptake amounts confirm that fall rye planting combined with early spring control resulted in low residual N uptake. The trend of wet conditions in the years of study also resulted in low residual soil nitrate, which caused the rye to be N-supply limited.

Table 2. Rye cover crop N uptake before controlling growth with herbicide, 2009-2013.

Cover Crop	lb N/acre <sup>†</sup>	Ames	Crawfordsville	Lewis	Nashua	Sutherland
		----- lb N/acre -----				
Before corn		20	26	18	14	8
Before soybean	0	18c <sup>‡</sup>	19b	16b	13b	13a
	120	25b	23b	22a	15b	17a
	200	42a	35a	24a	22a	19a

<sup>†</sup> Nitrogen rate applied to the prior year corn.

<sup>‡</sup> Rye total N amounts at a site followed by the same letter are not different,  $p \leq 0.10$ .

The study protocol intended to allow time for rye growth in the spring, but control the rye and plant corn and soybean crops in a timely manner. This resulted in a usually shortened period for spring rye growth and biomass production. When soils were wet and delayed planned field activities, this resulted in a longer period for rye growth and increased biomass accumulation and N uptake. However, those conditions also delayed corn and soybean planting.

### Soybean Yield

Except for the Ames site in 2009, where the soybean yield with rye was greater than without rye (data not shown), having winter rye in the no-till corn-soybean system had no effect on soybean yield (Table 3). The greatest potential for a soybean yield response to rye was at the Crawfordsville site since rye at that site often had a long spring period for growth (due to wet soils) and the largest biomass production; however, no statistical difference was observed in any year. During the five years of study, no visible growth issues or pest problems were observed at any site that might affect soybean production.

Table 3. Soybean grain yield with and without rye cover crop, 2009-2013.

Cover Crop	Ames	Crawfordsville	Lewis	Nashua	Sutherland
		----- bu/acre -----			
With cover crop	54.4a <sup>†</sup>	58.5a	58.5a	61.2a	63.3a
Without cover crop	53.5a	59.0a	58.1a	62.4a	62.8a

<sup>†</sup> Yields at a site followed by the same letter are not different,  $p \leq 0.10$ .

### Corn Nitrogen Response and Yield

Corn had large growth response to applied N each year and across years (Figure 1). The canopy NDVI values increased as N rate increased from zero N to a maximum response; at 78 lb N/acre with rye and 106 lb N/acre without rye. These plateau levels indicate deficit N at low rates and no further increase in canopy response at rates greater than plant need. The winter rye cover crop resulted in a lower maximum N rate response than without rye, but negatively impacted the corn mid-vegetative canopy development (lower plateau NDVI).

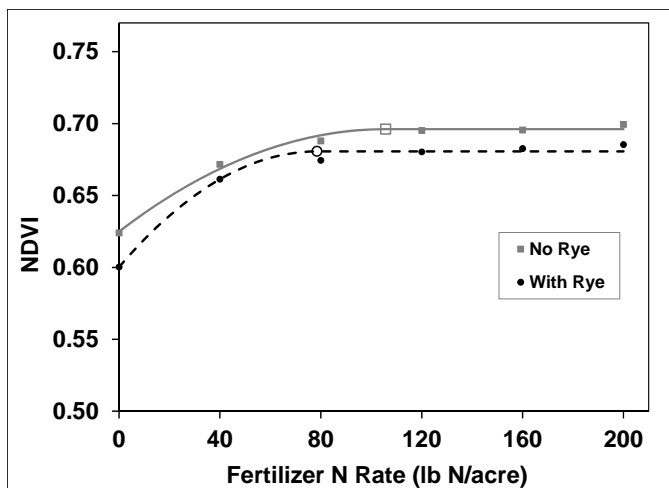


Figure 1. Corn plant canopy NDVI (mid-vegetative growth) response to N rate across sites and years with and without rye cover crop, 2009-2013. Open symbols indicate the maximum N response rate.

The five-year average EONR was similar with or without the rye cover crop (Figure 2), with a 6 lb N/acre higher EONR with the rye cover crop (157 vs. 151 lb N/acre). The EONRs were high for a soybean-corn rotation, a reflection of the overall wet conditions during the study years. The corn YEONR was 9 bu/acre lower (5%) with the rye cover crop (179 vs. 188 bu/acre). Across all N rates, corn yield was 8% lower with the rye cover crop, indicating greater yield difference at low N rates. Individual site-year yield differences are indicated in Figure 3. The small difference in corn N fertilization need between with and without the rye cover crop would be related to the low rye N uptake and low potential N recycling following the soybean crop.

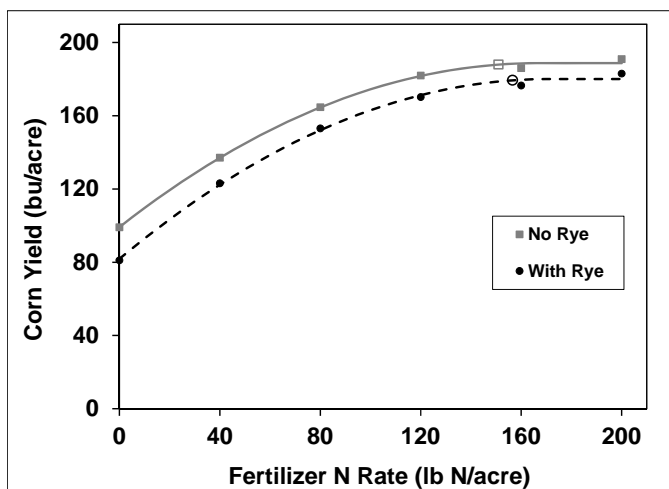


Figure 2. Corn grain yield response to N rate across sites and years with and without rye cover crop, 2009-2013. Open symbols indicate the economic optimum N rate (EONR).

The yield responses to the rye cover crop are a general reflection of the rye biomass effect on corn early growth. Although there was variation, the yield difference (corn yield without rye minus yield with rye) increased as the rye biomass amount increased (Figure 3). This relationship indicated that in a no-till corn-soybean system greater rye production could be a

negative factor for potential corn yield, but not for soybean yield. Overall, having corn planted after rye resulted in decreased yield and a small but higher corn N fertilization rate requirement. These results indicate potential for lower corn N use efficiency with the winter rye cover crop system.

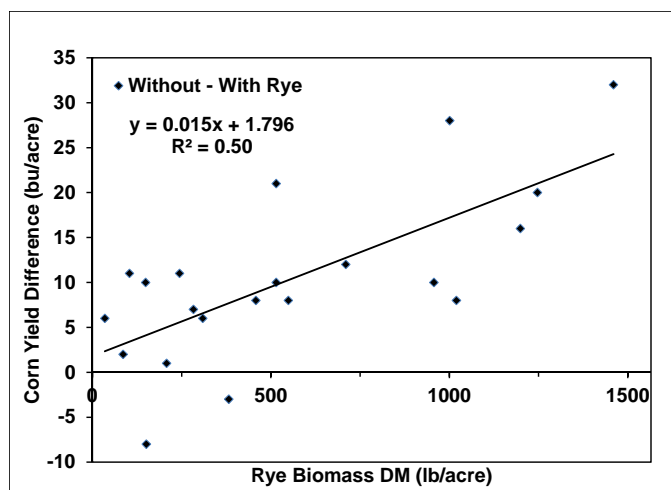


Figure 3. Corn grain yield difference (corn yield without rye minus yield with rye cover crop, at max N response) relationship to aboveground rye biomass dry matter (DM), 2009-2013.

## Summary

Including a winter cereal rye cover crop in the corn-soybean no-tillage cropping system had no effect on soybean grain yield, but resulted in reduced corn grain yield and a small increase in optimal N rate. The five years of study had frequent wet growing season conditions, which resulted in higher than normal response to applied N and EONR. Results of this study indicate that the N fertilization requirement was basically the same in a rye cover crop system as with no rye cover crop. Therefore, no change in N application rate would be required when transitioning to a winter rye cover crop system with rye planted between each corn and soybean crop and when rye biomass production and potential N recycling would be relatively low.

## Acknowledgments

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